

# **Modal Mapping in a Complex Shallow Water Environment**

George V. Frisk  
Bigelow Bldg. - Mailstop 11  
Department of Applied Ocean Physics and Engineering  
Woods Hole Oceanographic Institution  
Woods Hole, MA 02543  
Phone: (508) 289-2383    Fax: (508) 457-2194    email: [gfrisk@whoi.edu](mailto:gfrisk@whoi.edu)

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## **LONG-TERM GOALS**

The long-term goal of this research is to increase our understanding of shallow water acoustic propagation and its relationship to the three-dimensionally varying geoacoustic properties of the seabed.

## **OBJECTIVES**

The scientific objectives of this research are: (1) to develop high-resolution methods for characterizing the spatial and temporal behavior of the normal mode field in shallow water; (2) to use this characterization as input data to inversion techniques for inferring the acoustic properties of the shallow water waveguide; and (3) to use this characterization to improve our ability to localize and track sources.

## **APPROACH**

An experimental technique is being developed for mapping the wavenumber spectrum of the normal mode field as a function of position in a complex, shallow water waveguide environment whose acoustic properties vary in three spatial dimensions. By describing the spatially varying spectral content of the modal field, the method provides a direct measure of the propagation characteristics of the waveguide. The resulting model maps can also be used as input data to inverse techniques for obtaining the acoustic properties of the waveguide. The experimental configuration consists of a moored or towed source radiating one or more pure tones to a field of freely drifting buoys, each containing a hydrophone, GPS and acoustic navigation, and radio telemetry. In this context, two-dimensional modal maps in range *and* azimuth, as well as three-dimensional bottom inversion in range, depth, *and* azimuth, become achievable goals.

## **WORK COMPLETED**

Our major accomplishment this year was the successful execution of the third Modal Mapping Experiment (MOMAX III), which was conducted aboard the R/V Endeavor during the period 17-31 October 2000 in water depths ranging from 70 m to 1000 m. A series of five experiments was carried out during Leg 3 of the SWAT (Shallow Water Acoustic Technology) Experiment in the East Coast STRATAFORM/SWARM area off the New Jersey coast. The SWAT Experiment was a multi-institutional, multi-ship project that included U.S. investigators from the Naval Research Laboratory,

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the University of Miami, and WHOI as well as Japanese investigators from the Japan Defense Agency, OKI Electric Industry Co., and Ishikawajima-Harima Heavy Industries. Three drifting MOMAX buoys, each containing a hydrophone, GPS navigation, and radio telemetry, received signals out to ranges of 20 km from moored and towed sources transmitting pure tones in the frequency range 20-475 Hz. In addition to the acoustic measurements, extensive environmental data were also acquired, including: 3-6 kHz chirp sonar data; XBT, CTD, XCTD and temperature string measurements; and current, meteorological, and wave height data.

## **RESULTS**

A preliminary examination of these measurements indicates that the data are of very high quality and offer great promise for achieving the goals of the research. Specifically, the following scientific achievements were accomplished in MOMAX III:

- (1) The acoustic field at 20 Hz appears to be dominated by a single normal mode during one of the experiments, where the water depth is comparable to the acoustic wavelength of about 75 m. The evolution with range of the corresponding single modal eigenvalue can then be easily calculated by taking the range derivative of the measured acoustic phase.
- (2) The simple phase model developed from the MOMAX I and II data is further corroborated in MOMAX III for a broader range of frequencies (20-475 Hz), source-receiver speeds (up to 2 m/s), and source-receiver separations (up to 20 km). Specifically, the model indicates that the leading-order behavior of the time rate-of-change of the phase is equal to the product of a typical wavenumber in the water column and the source-receiver speed.
- (3) During one of the experiments at 50 Hz, the horizontal wavenumber spectra show a pronounced, range-dependent evolution for data obtained across the shelf versus a stable, essentially range-independent behavior for data obtained along the shelf. This is the first observation in the wavenumber domain of the strong range-dependent influence of a sloping bottom environment.
- (4) Measurements of Doppler-shifted wavenumber spectra due to a 50 Hz source first opening and then closing in range along the same track motivated the initial development of a new technique for measuring modal group velocity.

## **IMPACT/APPLICATIONS**

The experimental configuration consisting of a CW source and freely drifting buoys will provide a simple way to characterize a shallow water area and may be useful in survey operations. In addition, the planar, synthetic receiving array may offer an effective new technique for localizing and tracking CW sources in shallow water.

## **TRANSITIONS**

The synthetic aperture technique and Hankel transform inversion methodology which underlies the modal mapping method has been implemented in the ACT II experiment, sponsored by DARPA and ONR. This approach has also been adopted by several research groups internationally, including the Japanese groups involved in SWAT.

## RELATED PROJECTS

MOMAX was conducted in the same area off the New Jersey coast where the ONR-sponsored STRATAFORM, SWARM, and Geoclutter experiments were carried out. The extensive geophysical, seismic, acoustic, and oceanographic data obtained in these experiments are being used to ground truth the MOMAX measurements.

The LWAD 99-1 Project included a broad range of underwater acoustic and environmental measurements, in addition to MOMAX II. The results from these other experiments are being used to assist in the interpretation of the MOMAX II data.

We continued our collaborative effort with Professor Joyce McLaughlin's group in the Mathematical Sciences Department at the Rensselaer Polytechnic Institute. We are working together to apply exact, analytic inverse techniques developed, with partial ONR support, by her group to the problem of inverting for the geoacoustic properties of the seabed using our shallow water acoustic measurements as input data.

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